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Water Guidance and Monitoring Division

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Lawrence Livermore National Laboratory Experimental Test Site 300

Compliance Monitoring Program for the CERCLA-Closed Pit 6 Landfill

Annual Report 2007

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Summary

This monitoring report is required by the *Post-Closure Plan for the Pit 6 Landfill Operable Unit, Lawrence Livermore National Laboratory Site 300* (Ferry *et al.*, 1998). It summarizes post-closure compliance activities performed at the closed Pit 6 landfill during 2007, with special attention to results from the fourth quarter. Results from quantitative analyses by state-certified analytical laboratories of chemical constituents of concern (COCs) in ground water samples are summarized in the report and listed in the appendices.

COC measurements made during the fourth quarter of 2007 do not differ significantly from past quarters. Statistical limits (SL) for tritium, uranium, and volatile organic compounds (VOCs) were exceeded in samples collected from ground water wells in the Pit 6 complex during the fourth quarter. Tritium activities have been previously reported to the Central Valley Regional Water Quality Control Board (CVRWQCB). Total uranium activity in ground water samples from well EP6-08 exceeded the SL. Analytical results from retests of ground water samples from this well confirmed the initial result and a seven-day letter was submitted to the Remedial Project Managers (RPM) in accordance with the Post-Closure Plan. Trichloroethene (TCE) was also detected in ground water samples at concentrations greater than the statistical limit at the monitoring well (EP6-08), which has also been previously reported to the CVRWQCB. It is likely that the tritium, VOCs, and perchlorate detected in ground water samples throughout 2007 are related to past releases from the landfill prior to its closure in 1998. All required inspections and surveys of the Pit 6 cap were performed during 2007, demonstrating the continued functional and structural integrity of the caps, vegetative cover, and drainage structures.

Introduction

Site 300 is the Lawrence Livermore National Laboratory (LLNL) Experimental Test Facility located in the Altamont Hills approximately 10.5 kilometers (km) (6.5 miles [mi]) southwest of downtown Tracy, California (**Figure 1**). Site 300 is owned by the United States Department of Energy (DOE) and is a 30.3 km^2 (11.8 mi^2) area site operated by Lawrence Livermore National Security, LLC. The closed Pit 6 landfill is located within Site 300 near its southern boundary (**Figure 2**). A post-closure plan requiring quarterly and annual reports of compliance monitoring activities at the Pit 6 landfill (Ferry *et al.*, 1998) was implemented during the second quarter of 1998.

Figure 1. Location of LLNL Site 300.

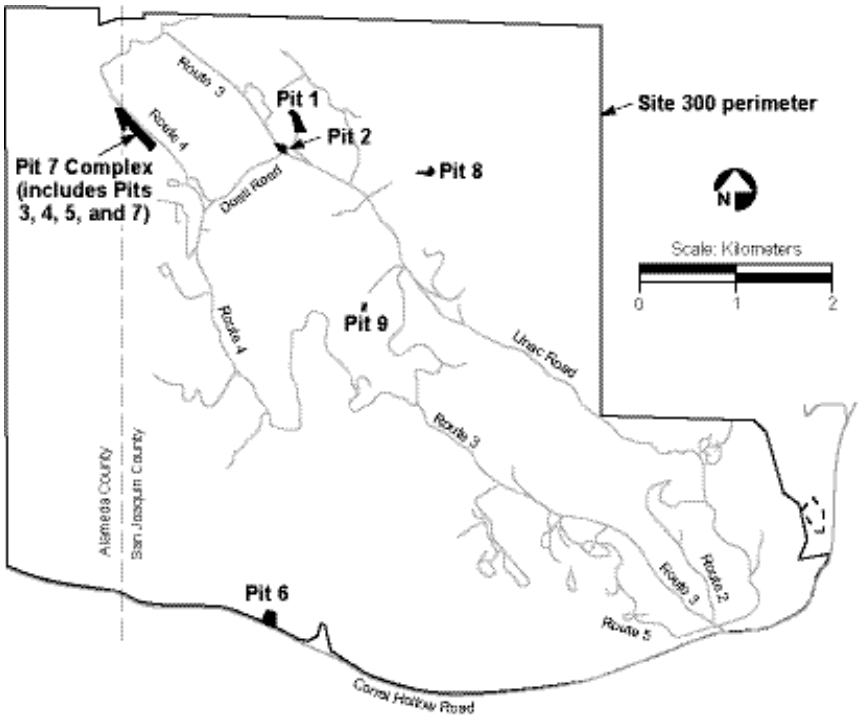

Figure 2. Location of Pit 6 at LLNL Site 300.

Figure 3 shows the locations of the wells that are used to monitor the ground water in the vicinity of the Pit 6 landfill, including upgradient wells, detection monitoring wells, and corrective action monitoring wells (Ferry *et al.*, 1998). The northern limit of the Carnegie-Corral Hollow Fault zone extends beneath Pit 6 as shown in **Figure 3**. Ground water flows southeastward, following the inclination (dip) of the underlying sedimentary rocks. Depth to the water table ranges from 10 to 20 meters (m) or 32.8 to 65.6 feet (ft) in terrace deposit gravels within the fault zone beneath Pit 6. Ground water flows within these gravels to the east-southeast parallel to the Site 300 boundary fence line (Webster-Scholten, 1994).

Monitoring Program Overview

The primary post-closure monitoring activity performed by LLNL at Pit 6 is the quarterly collection of ground water samples for chemical analyses. Field measurements of ground water physical parameters are collected at the time of sampling. Two ground water monitoring programs have been implemented at the Pit 6 landfill to ensure compliance with regulations. The Detection Monitoring Program (DMP) detects any new release of constituents of concern (COCs) to ground water from wastes buried in the Pit 6 landfill, while the Corrective Action Monitoring Program

(CAMP) monitors the movement and fate of historically-released contaminants of concern in the ground water. COCs, as defined by Title 23 of the *California Code of Regulations* (CCR), Chapter 15, are waste constituents, reaction products, and hazardous constituents that are reasonably expected to be in or derived from waste buried in the Pit 6 landfill. Contaminants of concern differ from COCs and are chemical and radioactive constituents that were identified and monitored under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) including tritium activity, volatile organic compounds (VOCs), nitrate, and perchlorate. The acronym COC will only be used to refer to constituents of concern, not contaminants of concern.

Twenty-four COCs, including some VOCs and radioisotopes, were identified initially for monitoring (Ferry *et al.*, 1998). Perchlorate and nitrate were discovered subsequently in the ground water near Pit 6 during Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site-wide surveys. Perchlorate was added to the COC list, and quarterly monitoring and reporting on it began during the third quarter of 2000. Since January 2003, an expanded set of CAMP wells (**Figure 3**) have been monitored for tritium activity, additional VOCs, nitrate, and perchlorate. Additional changes to the monitoring program implemented since January 2003 are discussed in **Appendix D**.

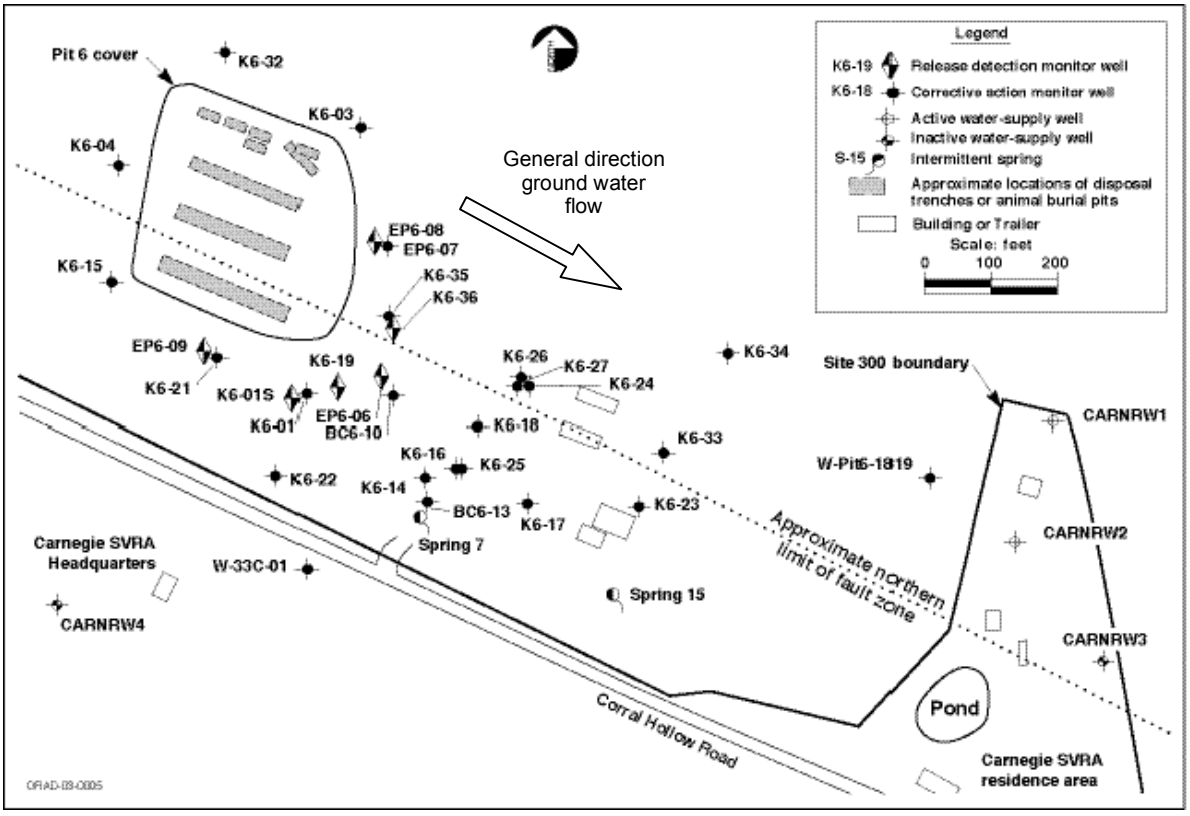

Figure 3. Locations of Pit 6 monitoring wells.

As required by DOE Order 241.1, our measurements are reported in *Système Internationale* (SI) units. The SI unit for radioactivity is the becquerel (Bq), equal to 1 nuclear disintegration per second. The more commonly used unit, the picocurie (pCi), is equal to 1 nuclear disintegration per 27 seconds. As a convenience, maximum contaminant levels (MCLs) for radioactivity in drinking water are given in both becquerels per liter (Bq/L) and picocuries per liter (pCi/L) in **Table 1,** below. Note that MCLs are provided for reference only, because this report does not involve wells used for potable domestic, livestock, or industrial water supply.

Table 1. MCLs for radioactivity in drinking water.

Radiological parameter	**MCL** (Bq/L)	**MCL** (pCi/L)
Gross alpha	0.555	15
Gross beta	1.85	50
Tritium	740	20,000
Uranium (total)	0.74	20

DMP objective. The primary DMP objective is to detect any new release of COCs to ground water. Ground water is sampled quarterly from six wells located hydraulically downgradient of Pit 6 along the point of compliance. These wells are identified as EP6-06, EP6-08, EP6-09, K6-01S (K6-01 if K6-01S is dry), K6-19, and K6-36 in **Figure 3**. Water samples are sent to state-certified laboratories where they are analyzed quantitatively for the presence (or absence) of COCs (see **Table C-1** for the list of DMP COCs). Gross alpha and gross beta radioactivity measurements are used as surrogates for seven radionuclide COCs other than uranium and tritium. Additional field measurements of ground water general parameters are obtained quarterly at the time of sample collection.

Potential releases of COCs from Pit 6 are indicated by comparing analytical results for ground water samples with statistically-determined limits of concentration, called statistical limits, or SLs (see **Appendix C**, **Table C-1**, for the list of COCs and their respective SLs). If a COC measurement exceeds an SL, the measurement is investigated further to determine its validity. Consistent with state regulations, two independent ground water samples, called retest samples, are obtained at least one week apart from the associated monitoring well and analyzed for the suspect COC. If the COC is present in either sample at a concentration that exceeds the SL, then the initial analysis is deemed to be validated and it is reported as statistically significant evidence of a release. If neither retest sample measurement exceeds the SL, then the initial

exceedance is not confirmed, and a release report is not made. Any further investigation of a COC is at the discretion of the Site 300 Remedial Project Managers (RPMs) and is conducted by LLNL under CERCLA.

CAMP objectives. The primary CAMP objectives are to: (1) evaluate the effectiveness of the corrective action; (2) evaluate natural attenuation of the ground water VOC and tritium plumes; (3) monitor perchlorate and nitrate in ground water; and (4) evaluate the need for implementing contingency actions. To accomplish the CAMP objectives, ground water measurements from the monitoring wells shown in **Figure 3** are evaluated on a quarterly basis as directed by the CAMP sampling plan.

Several VOCs, tritium, and perchlorate were released to ground water from Pit 6 prior to its closure. VOCs, primarily the solvents tetrachloroethene (PCE) and trichloroethene (TCE), have been described and evaluated previously in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300* (Webster-Scholten, 1994), the *Final Feasibility Study for the Pit 6 Operable Unit, Lawrence Livermore National Laboratory Site 300* (Devany *et al*., 1994), the *Addendum to the Pit 6 Engineering Evaluation/Cost Analysis, Lawrence Livermore National Laboratory, Site 300* (Berry 1996), the *Final Site-Wide Feasibility Study for Lawrence Livermore National Laboratory Site 300* (Ferry *et al*., 1999), and the *Interim Site-Wide Record of Decision for Lawrence Livermore National Laboratory Site 300* (DOE, 2001).

In previous Compliance Monitoring Program reports for the Pit 6 Landfill, ground water VOC concentration maps have been presented for TCE only. Starting in 2004, a new format for presenting CAMP VOC data was used to maintain consistency with the CERCLA Compliance Monitoring Report. In this report, the concentrations of all VOCs detected in ground water monitoring wells in the Pit 6 area have been summed and are presented as Total VOCs (TVOCs). The concentrations of individual compounds contributing to the TVOC concentration in each well are included in **Appendix B**, **Table B-2**.

Tritium activity is above background in ground water downgradient from Pit 6, suggesting that a localized tritium release occurred prior to pit closure (Ferry *et al*., 1998). Monitored natural attenuation is the interim remedial action selected for the tritium plume.

Additional post-closure activities for Pit 6 include: (1) inspection of the landfill cap by LLNL technical staff annually and following major storms; (2) an annual comprehensive inspection of the landfill by an independent state-certified Professional Engineer (PE); (3) an annual pit cap elevation survey; (4) repairs as necessary to maintain the integrity of the landfill cap, its water diversion system, and its network of

monitoring wells; and (5) preparation of reports. Reports of post-closure activities are provided quarterly to the participating regulatory agencies for their information and use.

Quality Assurance

To ensure data quality, LLNL works within the established Quality Assurance (QA) program of the LLNL Environmental Protection Department (EPD). LLNL uses protocols and procedures that cover all aspects of ground water sampling, sample tracking, and data management. These written protocols and procedures are contained in the *LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures (SOPs)* (Goodrich and Wimborough, 2006), the *Environmental Monitoring Plan* (Woods, 2005), and the *EPD Quality Assurance Management Plan* (Clark, 2006). Data quality is assessed by the following four methods: (1) analytical results for the routine and duplicate samples are compared by the analysts responsible for this report; (2) field blank samples are submitted to the analytical laboratories together with the routine ground water samples for identical analyses; (3) equipment blanks are prepared and analyzed to ensure that sampling equipment is properly cleaned before use; and (4) when samples are collected for VOC analysis, a trip blank (prepared at the analytical laboratory) is carried into the field. A summary of QA results may be found in **Appendix E, Table E-1**.

DMP Summary for 2007

COC measurements for the DMP wells are listed in **Appendix A**, **Table A-1**. Field measurements of ground water parameters and analytical laboratory measurements of total dissolved solids (TDS) for the DMP wells are listed in **Appendix A**, **Table A-2**. Data collected during the fourth quarter of 2007 do not differ significantly from past quarters (see Campbell and Taffet, 2007), other than some minor exceptions discussed below.

As in the previous quarter, TCE was detected at concentrations greater than the SL in ground water samples from well EP6-08 of 0.6 μg/L (SL = 0.5 μg/L). TCE concentrations at this monitoring well have been previously reported to the CVRWQCB (Goodwin, 2007). It appears that the TCE likely originates from the existing VOC plume from releases that occurred at the landfill prior to its closure in 1998. VOC concentrations in ground water samples from this well are also discussed in the CAMP section.

Total uranium activity in a ground water sample collected at monitoring well EP6-08 exceeded the SL during the fourth quarter (0.07 Bq/L [1.88 pCi/L], SL = 0.06 [1.62 pCi/L]). Resampling and reanalysis results for ground water samples collected one week apart on January 14, 2008, and January 22, 2008, confirmed the initial finding with total uranium activities of 0.08 Bq/L and 0.10 Bq/L (2.11 pCi/L and 2.64 pCi/L), respectively (**Table A-1**). A letter reporting the results was sent to the Remedial Project Managers (Jackson, 2008). Although the results exceeded the SL, the total uranium activities observed are still relatively low at less than 14% of the drinking water MCL listed in **Table 1**. Additional analyses will be performed and reported during the first and second quarters of 2008. These analyses will include examining data from nearby monitoring wells and collecting, as well as analyzing, ground water samples for mass spectrometric uranium analyses to examine uranium-235/uranium-238 mass ratios.

A few additional contaminants of concern that were released to ground water from the landfill prior to its closure in 1998 continue to be detected, including tritium and VOCs (**Table A-1**). Tritium activities continue to exceed the SL of 3.7 Bq/L (100 pCi/L) in ground water at downgradient DMP wells K6-01S (4.0 Bq/L [108 pCi/L]) and K6-19 (8.2 Bq/L [222 pCi/L]). Tritium activities have remained well below the EPA drinking water MCL of 740 Bq/L (20,000 pCi/L) and the California Public Health Goal of 14.8 Bq/L (400 pCi/L) at these wells and activities appear to be relatively stable or decreasing. For a more detailed account and map of the Pit 6 tritium activities and TVOC concentrations, see the following CAMP summary. Historical tritium activities for these two monitoring wells and well K6-36 are displayed in **Figure 4**.

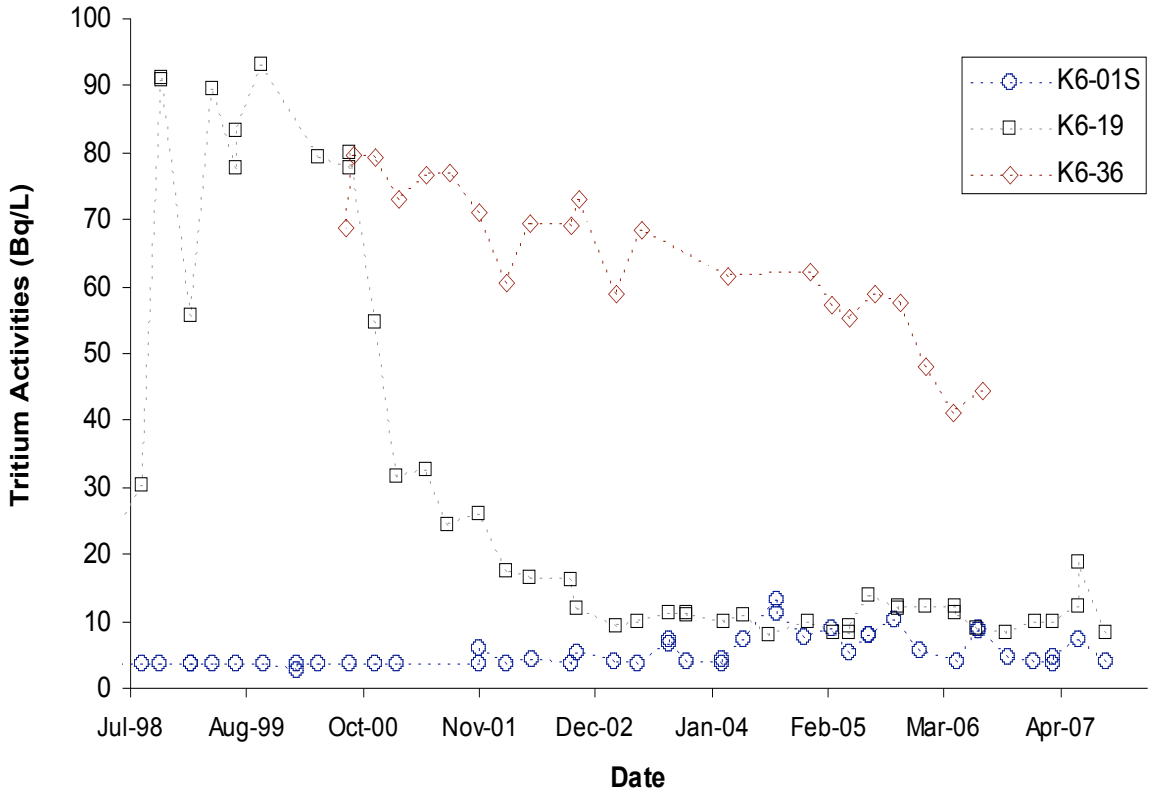

Figure 4. Historical tritium activities at Pit 6 monitoring wells K6-01S, K6-19, and K6-36s.

Total VOCs (TVOCs) results from Pit 6 monitoring wells are presented in the following CAMP summary. The VOC accounting for the largest proportion of the TVOCs is TCE. Therefore, the historical values for TCE concentrations measured in water samples collected from ground water monitoring wells EP6-09, K6-01S, and K6-19 are in **Figure 5**. The TCE concentrations also generally appear to be stable or decreasing. For a more detailed account and map of the Pit 6 tritium activities and TVOC concentrations, see the following CAMP summary.

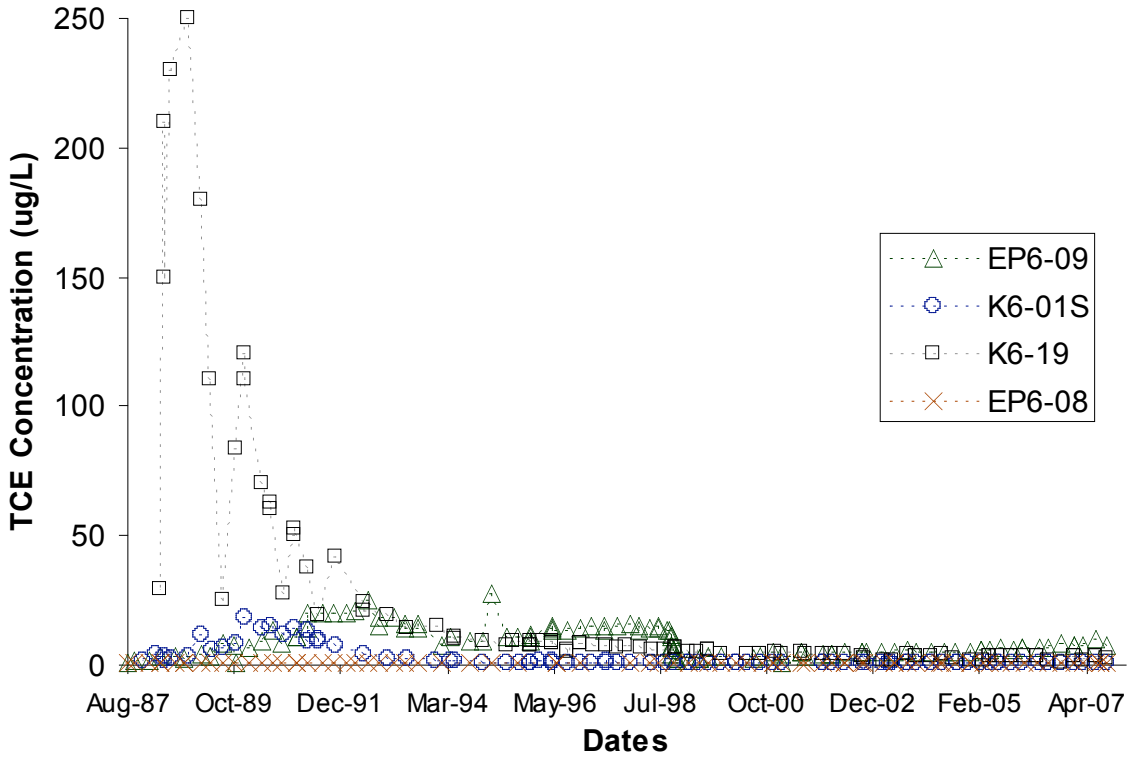

Figure 5. Historical TCE concentrations at Pit 6 monitoring wells EP6-08, EP6-09, K6-01S, and K6-19.

CAMP Summary for 2007

This section summarizes an analysis of ground water elevation and contaminant of concern data collected during the fourth quarter of 2007. The primary COCs for the Pit 6 area are several VOCs and tritium (Ferry *et al.*, 1998). Perchlorate and nitrate were subsequently detected at concentrations above the State MCL for drinking water in ground water samples from several Pit 6 monitoring wells during site-wide investigations by LLNL. Perchlorate was designated a secondary contaminant of concern in 2000. Beginning in 2003, nitrate also became a secondary contaminant of concern. Ground water elevations for the fourth quarter of 2007 are listed in **Table B-1**. Detections of VOCs, tritium, perchlorate, and nitrate in ground water samples collected during the fourth quarter are listed in **Tables B-2, B-3,** and **B-4**, respectively.

Ground water elevations (GWE). Figure 6 is a ground water elevation contour map for the fourth quarter of 2007. Ground water elevations beneath Pit 6 are approximately a minimum of 10 m (30 ft) below the buried waste trenches. During the three-month period between the end of the third quarter of 2007 and end of the fourth quarter of 2007, ground water elevations north and south of the Corral Hollow-Carnegie Fault Zone generally declined. Elevations north of the fault zone decreased a

maximum of over 26 centimeters [cm] (0.87 ft) north of the fault zone and east of Pit 6 but decreased slightly (less than 9.1 cm or 0.3 ft) in the area adjacent to Pit 6. Ground water elevations within the fault zone decreased a maximum of about 1.9 cm (0.06 ft).

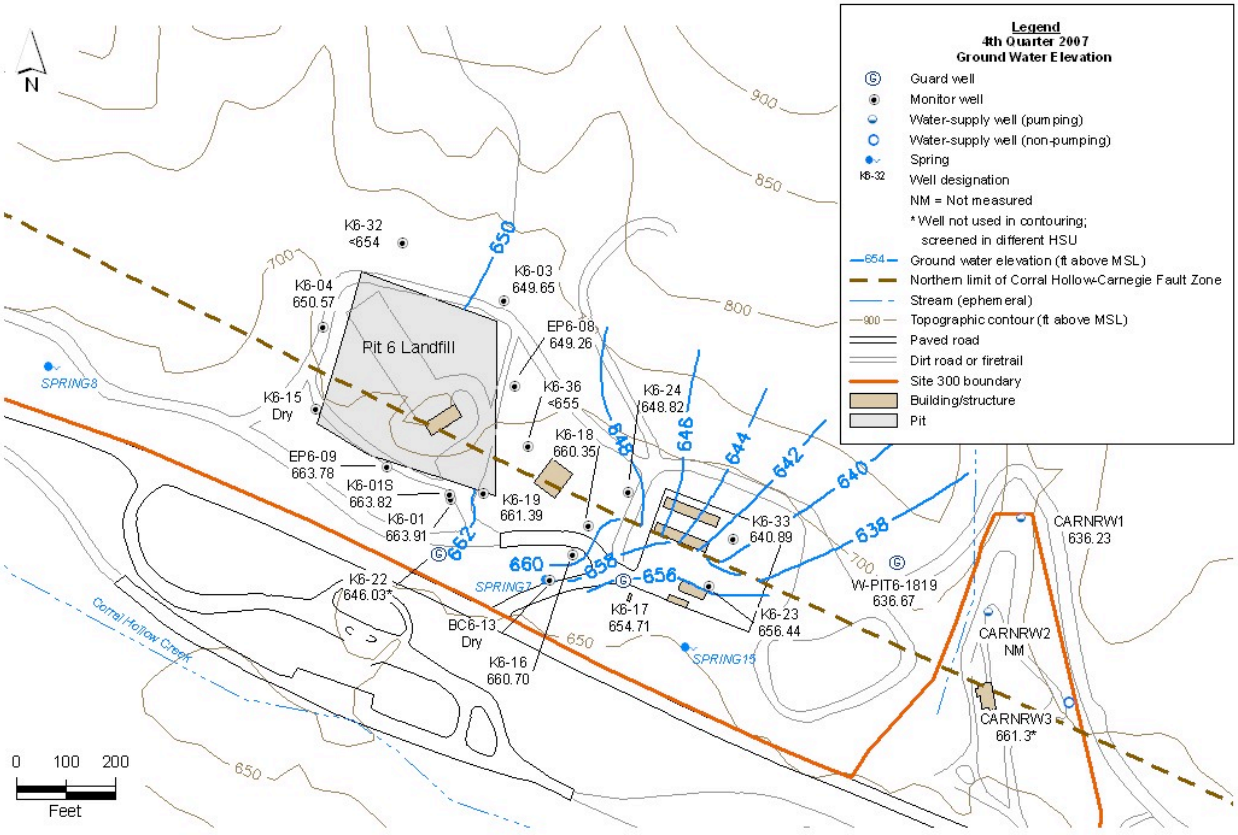

Figure 6. Ground water elevations (ft above MSL) in the first water-bearing zone at Site 300 Pit 6, fourth quarter 2007.

The predominantly southeast flow direction shown on **Figure 6** is consistent with potentiometric surface maps from previous quarters. Within the fault zone, ground water flows to the southeast with a hydraulic gradient of approximately 0.03. North of the fault zone, ground water flows to the southeast with a hydraulic gradient of approximately 0.01–0.02. Fractures in the Neroly formation $Tnbs_1$ stratigraphic unit play a dominant role in conveying ground water flow. A large component of the flow north of the fault is affected by pumping from offsite water-supply wells CARNRW1 and CARNRW2. As can be seen in the eastern portion of **Figure 6**, and especially in the vicinity of well W-PIT6-1819, ground water elevations north of the fault zone are strongly influenced by pumping from these wells. However, ground water elevations to the south, within the fault zone, do not appear to be strongly influenced by pumping.

Ground water TVOC concentrations. As shown in **Figure 7**, the concentrations of all the VOCs detected in ground water samples collected at Pit 6 during the fourth quarter of 2007 have been summed and are presented as TVOCs. TCE, PCE, and cis-1,2-DCE were the only VOCs detected at Pit 6 in ground water at concentrations above the method reporting limit of 0.5 micrograms per liter (μg/L) (for each compound) during the fourth quarter 2007.

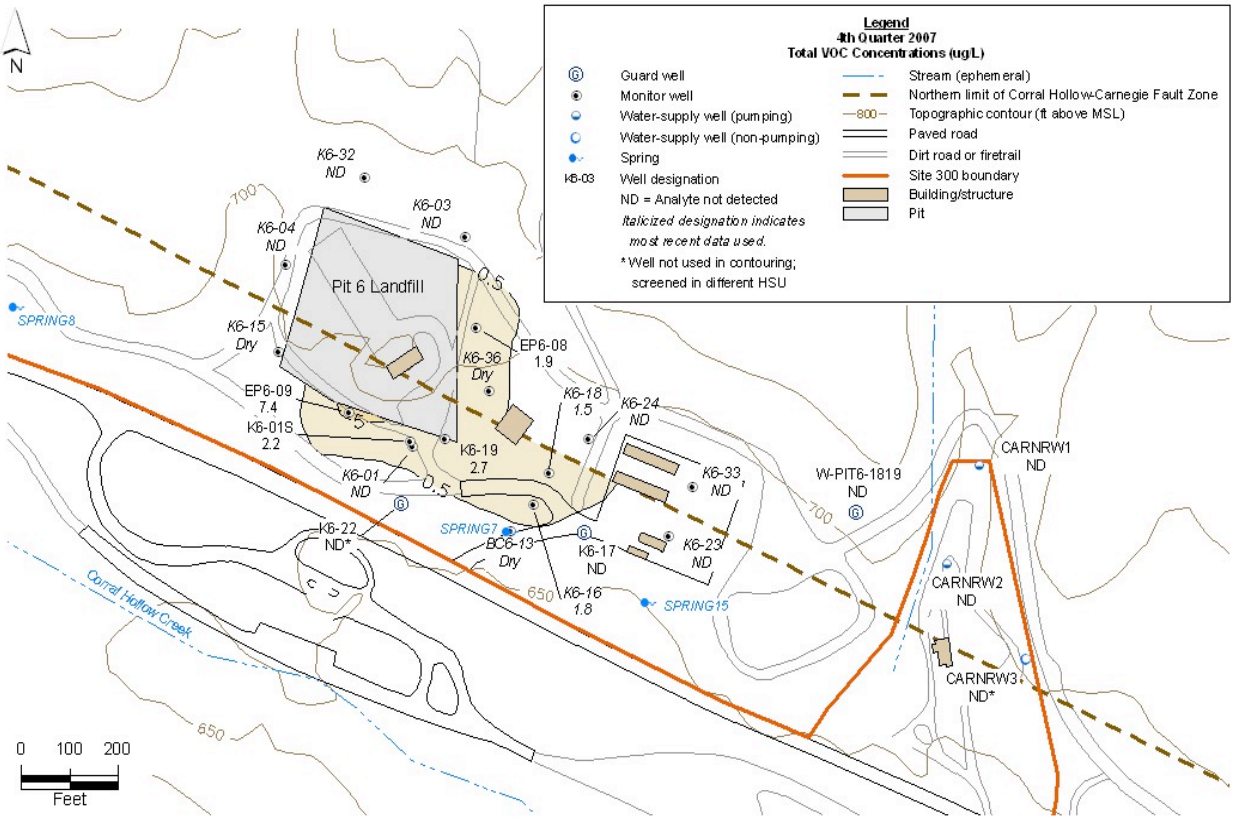

Figure 7. Ground water TVOC concentrations (*μg*/L) in the first water-bearing zone at Site 300 Pit 6, fourth quarter 2007.

The distribution of TVOCs depicted on **Figure 7** is similar to last quarter's. The maximum TVOC concentration this quarter was the 7.4 μg/L detected in the sample from well EP6-09; the only VOC detected in this sample was TCE. Last quarter, this well also yielded the maximum concentration of TVOCs at Pit 6 (9.8 μg/L). TVOCs were detected last quarter in ground water samples from monitoring wells EP6-08, EP6-09, K6-01S, K6-16, K6-18, and K6-19. Two of the wells that yielded VOCs last quarter, wells K6-16 and K6-18, were not sampled this quarter and are only sampled twice a year (during the first and third quarters) per CERCLA Comprehensive Monitoring Plan (CMP) requirements. TVOCs were again detected in ground water samples from the remaining four wells during the fourth quarter. Well K6-36 has been

dry since the fourth quarter 2006, but we have conservatively assumed that the water-bearing zone is saturated below the pump intake of the well screen. When last yielding water during the third quarter of 2006, the collected sample contained a TVOC concentration of 0.8 μg/L. Together, all these wells define a localized VOC plume that originates in the east-central portion of Pit 6. The concentrations of individual VOCs in ground water samples collected during the fourth quarter of 2007 are listed in **Table B-2**.

Ground water TCE concentrations during the fourth quarter of 2007 were similar to those detected in previous quarters and years. The maximum TCE concentration at Pit 6 this quarter was 7.4 μg/L in the ground water sample collected from well EP6-09, and was the only sample that met or exceeded the 5 μg/L MCL. Two other wells, K6-19 and EP6-08, yielded samples containing TCE in excess of the 0.5 μg/L detection limit, but below the MCL.

Ground water samples collected from this well during the previous three quarters contained 9.8, 7.6, and 7.7 μg/L of TCE. The maximum historical TCE concentration for ground water from this well was 28 μg/L in January 1995. By year, the maximum TCE concentrations measured in ground water at Pit 6 were 6.3 μg/L in 2000 (well K6-18), 5.4 μg/L in 2001 (well K6-19), 5.1 μg/L in 2002 (well EP6-09), 5.5 μg/L in 2003 (well EP6-09), 5.4 μg/L in 2004 (well EP6-09), 6.4 μg/L in 2005 (well EP6-09), 8.5 μg/L in 2006 (well EP6-09), and 9.8 μg/L (well EP6-09) in 2007. Monitoring data do not indicate a new release of TCE, or other VOCs, to ground water from Pit 6 during this quarter or year.

As in the past, cis-1,2-DCE was detected in a ground water sample from Pit 6. During the fourth quarter of 2007, 2.2 μg/L of cis-1,2-DCE were detected in the ground water sample from well K6-01S. cis-1,2-DCE has never been detected at or above the 70 μg/L Federal MCL, 60 μg/L State MCL or 100 μg/L State PHG in samples from any well in the Pit 6 area. Last quarter, cis-1,2-DCE was detected in one ground water sample, from well K6-01S, at a concentration of 2.3 μg/L. The most recent previous detections of cis-1,2-DCE (first, second, third, and fourth quarters of 2006 and first and second quarters of 2007) in samples from this well were 2.5, 2.4, 2.3, 1.7, 2.3, and 2.4 μg/L, respectively. The presence of cis-1,2-DCE, a degradation product of TCE, suggests that natural decomposition may be occurring.

This quarter, PCE was detected in a ground water sample from one well, EP6-08, at a concentration of 1.3 μg/L, below the 5 μg/L MCL for PCE. During the last three previous quarters of 2007, PCE was detected at concentrations of 1.4 μg/L, all three quarters, in samples from this well. Until the fourth quarter 2006, PCE had not been

detected in Pit 6 ground water since the third quarter of 2005. During the third quarter of 2005, 0.77 μg/L of PCE was detected in the ground water sample from well EP6-08. The previous detection (second quarter 2005) for this well was 0.97 μg/L. PCE was also detected in the third quarter 2005 ground water sample from well K6-36 at a concentration of 0.6 μg/L. Other recent detections of PCE in ground water from well K6-36 were 0.64 μg/L during the second quarter of 2005 and 0.68 μg/L during the first quarter of 2005.

This quarter, TCE, 1,2-DCE, and PCE were the only VOCs detected in Pit 6 ground water samples. During the third quarter of 2007, a sample collected from well EP6-08 on July 2, 2007 yielded 0.78 μg/L of chloroform. A confirmation sample collected from the well on August 9, 2007 contained 0.55 μg/L of chloroform. Well EP6-08 was the only well sampled at Pit 6 during the quarter that yielded more than one VOC in a ground water sample. The sample collected on July 2, 2007 contained 0.78 μg/L of chloroform, 1.7 μg/L of PCE, and 0.83 μg/L of TCE, resulting in 3.3 μg/L of TVOCs

Ground water tritium activity. **Figure 8** shows the areal distribution of tritium activities in ground water for the fourth quarter of 2007. This quarter, tritium activities in excess of the 3.7 Bq/L (100 pCi/L) detection limit were found in ground water samples from well W-PIT6-1819, north of the fault zone and from wells K6-01S and K6-19 within the fault zone. Tritium was not detected at or above the 740 pCi/L (20,000 pCi/L) MCL or the 14.8 Bq/L (400 pCi/L) State PHG in samples from any wells in the Pit 6 area. Last quarter, the detection limit for tritium analysis varied from 3.7 to 7.4 Bq/L (100 to 200 pCi/L). During the first and third quarters, a larger number of wells are sampled per CMP requirements. Last quarter, wells K6-24 and K6-33, north of the fault zone, and wells K6-01, K6-18, and K6-19 within the fault zone yielded ground water samples containing tritium activities equal to or in excess of the 3.7 to 7.4 Bq/L (100 to 200 pCi/L) detection limit. Well K6-36 was dry during the last four quarters, but when a sample was last collected during the third quarter 2006, the sample contained a tritium activity of 44.4 Bq/L (1,200 pCi/L). Thus, the 1,200 pCi/L tritium activity was conservatively used for the contouring depicted on **Figure 8**.

This quarter the highest tritium activity in Pit 6 ground water, 8.2 Bq/L (221 pCi/L), was found in the sample from well K6-19, located at the southeast corner of Pit 6. Last quarter, the sample from this well contained the maximum tritium activity at Pit 6 of 18.6 Bq/L (503 pCi/L). This quarter, well W-PIT6-1819 yielded a sample containing 6.4 Bq/L (173 pCi/L) of tritium. This well is a guard well and is used to define the downgradient extent of the tritium plume north of the fault zone. It is located about 30 m (100 ft) west of the Site 300 boundary with the Carnegie State Vehicle Recreation Area residence area and about 60 m (200 ft) west of the CARNRW1

and CARNRW2 water-supply wells (**Figure 8**). Last quarter, the sample from well W-PIT6-1819 contained < 3.7 Bq/L (100 pCi/L) of tritium. During the second quarter 2007, the highest measured ground water tritium activity at Pit 6 was 10.9 Bq/L (295 pCi/L) in the sample collected from well W-PIT6-1819. In recent past quarters, the ground water samples from well W-PIT6-1819 have contained tritium activities between < 3.7 Bq/L (100 pCi/L) and 10.9 Bq/L (295 pCi/L) of tritium. The third detection of tritium this quarter (4 Bq/L [108 pCi/L]) was in the ground water sample from well K6-01S, less than 100 ft west of well K6-19.

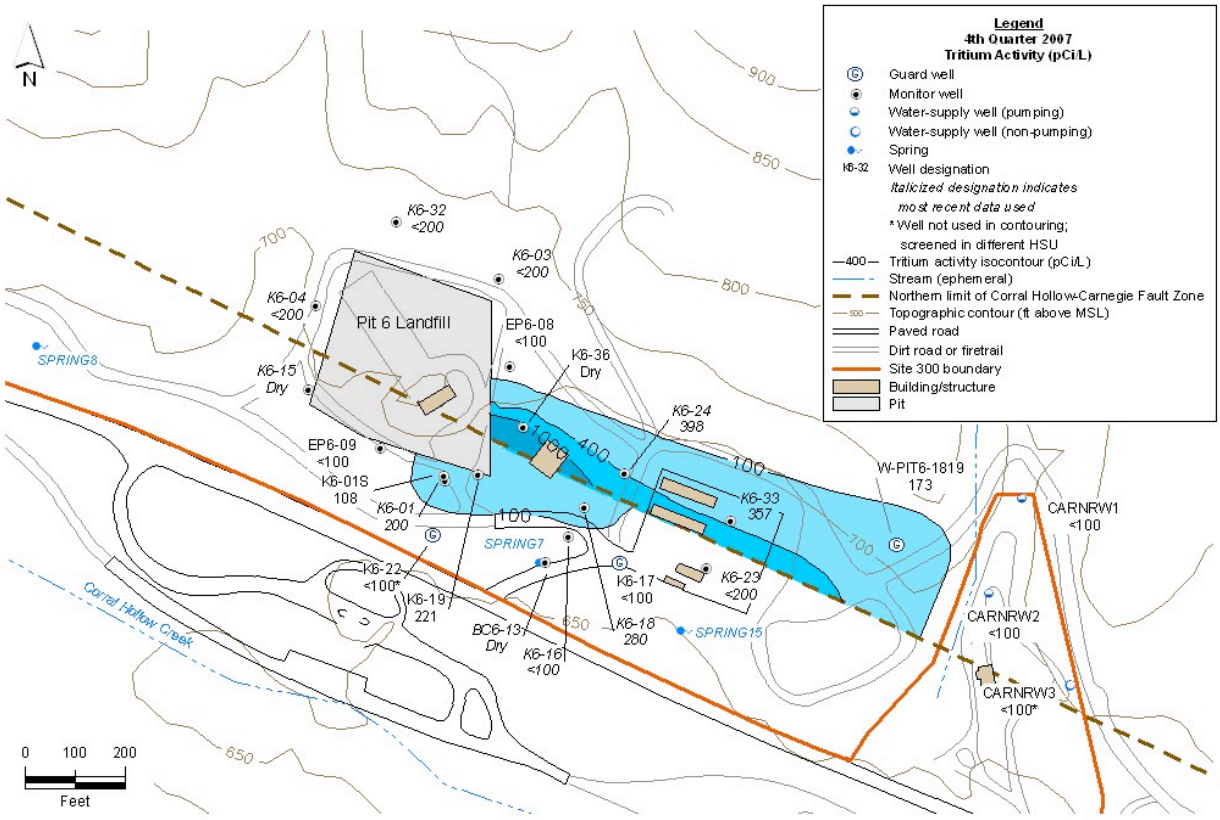

Figure 8. Ground water tritium activities (pCi/L) in the first water-bearing zone at Site 300 Pit 6, fourth quarter 2007.

Tritium activities were below the detection level of 3.7 Bq/L (100 pCi/L) in the monthly ground water samples obtained during the fourth quarter of 2007 from the off-site CARNRW wells. Based on these analyses and the results from other wells, the tritium plume appears to be relatively stable to declining in extent. Tritium activities in ground water samples from monitoring wells within the plume are generally decreasing.

Ground water perchlorate concentrations. A map showing fourth quarter 2007 perchlorate concentrations in ground water samples collected from the shallow

water-bearing zone is presented in **Figure 9**. This quarter, as well as the last two quarters, there were no wells that yielded perchlorate at or in excess of the reporting limit of 4 μg/L or the 6 mg/L State PHG. During the first quarter of 2007, K6-18 was the only well that yielded perchlorate in excess of the reporting limit at a concentration of 6.6 μg/L. The State MCL for perchlorate in drinking water is 6 μg/L. During the fourth quarter of 2006, one well, EP6-09, yielded a ground water sample that contained perchlorate in excess of the reporting limit (4.6 μg/L). During the previous two quarters, none of the wells yielded ground water samples containing perchlorate concentrations at or above the reporting limit of 4 μg/L. During the first quarter of 2006, two wells yielded ground water samples containing perchlorate. Wells EP6-09 and K6-18 yielded samples containing 6.7 and 10 μg/L of perchlorate, respectively. In the past, the maximum perchlorate concentrations in ground water at Pit 6 have been measured at well K6-18 (15 μg/L in 2002, 14 μg/L in 2003, and 14 μg/L in 2004). Perchlorate was not detected in ground water samples collected from the Pit 6 area during 2005.

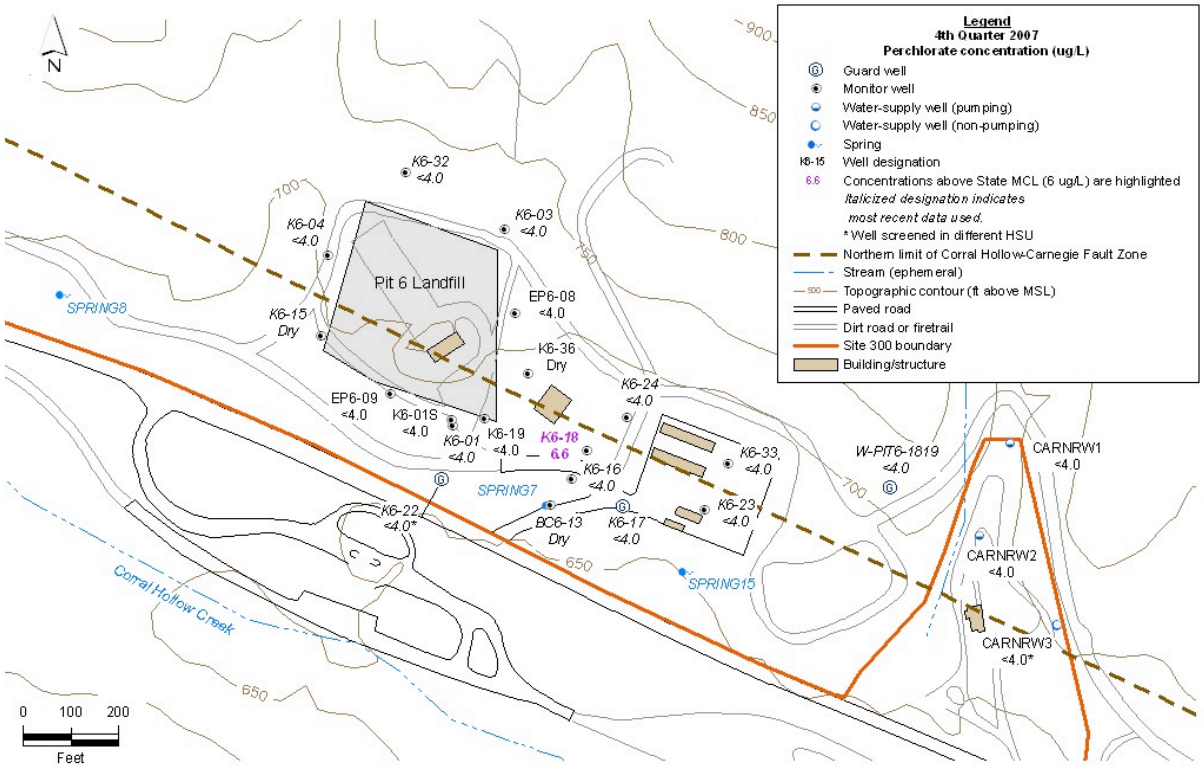

Figure 9. Ground water perchlorate concentrations (μg/L) in the first water-bearing zone at Site 300 Pit 6, fourth quarter 2007.

Ground water nitrate concentrations. A map showing fourth quarter 2007 nitrate concentrations in the shallow water-bearing zone at Pit 6 is presented in **Figure 10**. During the fourth quarter of 2007, nitrate was not detected above the 45 milligram per

liter (mg/L) MCL in any ground water samples. During the first quarter 2007, a ground water sample from well K6-23, contained nitrate in excess of the MCL (220 mg/L). This well consistently yields ground water nitrate concentrations in excess of the MCL and is sampled annually during the first quarter for this secondary contaminant of concern. Therefore, a sample was not collected from the well this quarter. Ground water nitrate concentrations from this well are consistently the highest at Pit 6 and were 172, 165, 200, and 200 mg/L in 2003, 2004, 2005, and 2006, respectively. Well K6-23 is located in close proximity to the Building 899 septic system, which is a potential source of the nitrate at this location. All of the fourth quarter 2007 ground water samples from the four CARNRW wells contained < 0.5 mg/L of nitrate.

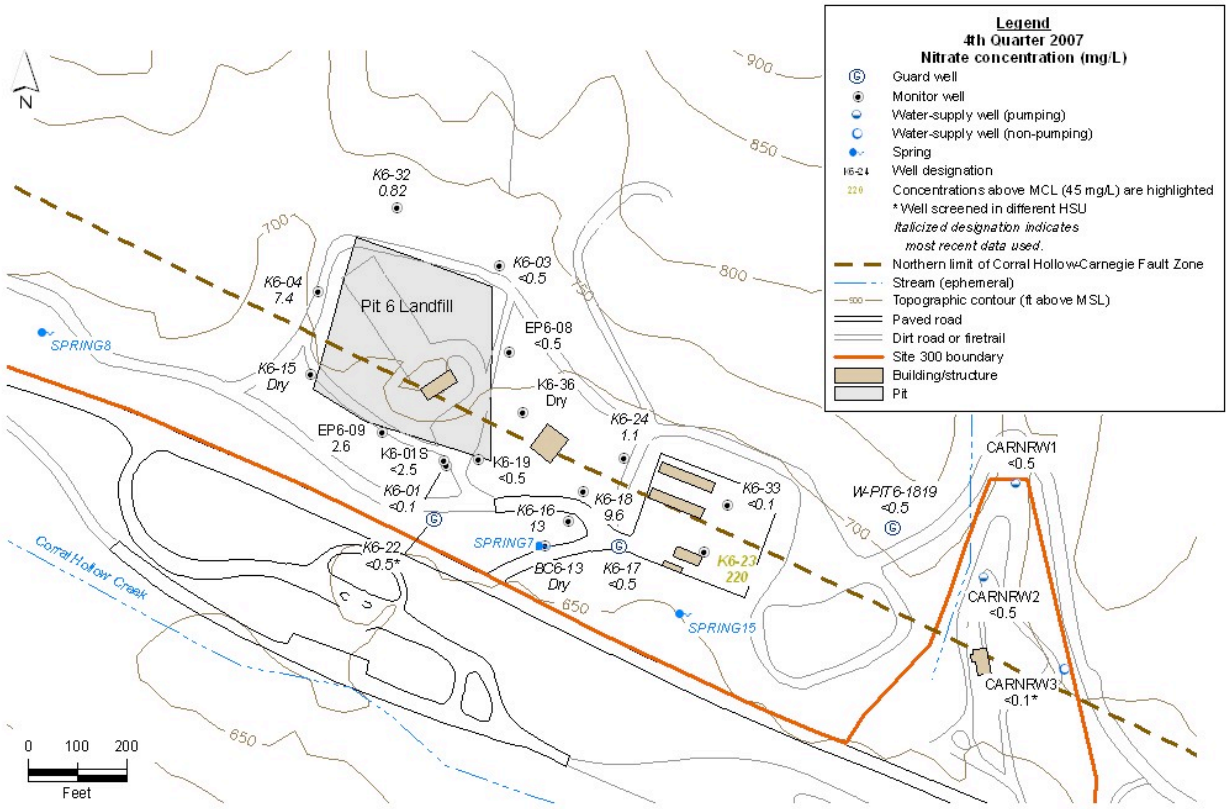

Figure 10. Ground water nitrate concentrations (mg/L) in the first water-bearing zone at Site 300 Pit 6, fourth quarter 2007.

Inspection and Maintenance Summary

The fourth quarter inspection of the Pit 6 cap was performed by LLNL staff. These quarterly visual cap inspections include a check list of issues related to cap integrity, vegetation, and drainage. No deficiencies were noted in the condition of the pit cap. The annual permanent marker elevation survey and inspection by a licensed P.E. were performed and reported for the Pit 6 during the second and third quarters of

2007. The survey and inspection did not identify major deficiencies; however, a continuing need to repair larger animal burrows and revegetate the area around the pistol range was noted. The pit cap and drainage structures continue to function adequately at Pit 6.

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Abbreviations and Acronyms

Bq	becquerel (international unit of radioactivity equal to 27 pCi)
CAMP	Corrective Action Monitoring Program
CB	Christy box
CC	control chart (statistical method)
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Cis-1,2-DCE	Cis-1,2-dichloroethene
CL	concentration limit (background concentration of a chemical)
COC	constituent of concern
CVRWQCB	Central Valley Regional Water Quality Control Board
DEHP	di(2-ethylhexyl)phthalate, bis(2-ethylhexyl)phthalate
DMP	Detection Monitoring Program
DOE	U.S. Department of Energy
DTSC	California Department of Toxic Substances Control
DUP	duplicate sample
EPA	U.S. Environmental Protection Agency
EPD	LLNL Environmental Protection Department
ERD	LLNL Environmental Restoration Division
ft	foot (used as a measure of elevation above MSL)
GWD	ground water depth
GWE	ground water elevation in feet above MSL
HSU	Hydrostratigraphic Unit
km	kilometer
L	liter
LLNL	Lawrence Livermore National Laboratory
m	meter
MCL	maximum contaminant level (for drinking water)
MSL	mean sea level (datum for elevation measurements)
mg	milligram
μg	microgram
nd	none detected
NM	not measured
PCB	polychlorinated biphenyl
PCE	perchloroethene, tetrachloroethene

pCi	picocurie (unit of radioactivity)
PE	Professional Engineer
PI	prediction interval (statistical method)
PQL	practical quantitation unit
QA	quality assurance
RL	reporting limit (contractual concentration near zero)
RPM	remedial project manager
RTN	routine sample
Site 300	Experimental Test Facility, LLNL
SL	statistically determined concentration limit
SOP	standard operating procedure
TCE	trichloroethene
TDS	total dissolved solids
THM	trihalomethane
$Tnbs_1$	Neroly Formation lower blue sandstone unit
TVOC	total volatile organic compound
VOC	volatile organic compound
WBZ	water bearing zone
yr	year

Appendix A

Tables of Ground Water Measurements for Detection Monitoring Wells

Table A-1. Pit 6 post-closure monitoring plan constituents of concern (COCs) detection monitoring wells, SLs, MCLs, and quarterly analytical results for 2007.

				Quarter			
COC (units)	**Well**	**SL**	**MCL**	**First**	**Second**	**Third**	**Fourth**
Metals (μg/L)							
Beryllium	EP6-06	0.2	4	< 0.5 [(a)]	< 0.5	< 0.5	< 0.2
	EP6-08	0.2		< 0.5	< 0.5	< 0.5	< 0.2
	EP6-09	0.2		< 0.5	< 0.5	< 0.5	< 0.2
	K6-01S	0.2		< 0.5	< 0.5	< 0.5	< 0.2
	K6-19	0.2		< 0.5	< 0.5	< 0.5	< 0.2
	K6-36	0.2		DRY	DRY	DRY	DRY
Mercury	EP6-06	0.2	2	< 0.2	< 0.2	< 0.2	< 0.2
	EP6-08	0.2		< 0.2	< 0.2	< 0.2	< 0.2
	EP6-09	0.2		< 0.2	< 0.2	< 0.2	< 0.2
	K6-01S	0.2		< 0.2	< 0.2	< 0.2	< 0.2
	K6-19	0.2		< 0.2	< 0.2	< 0.2	< 0.2
	K6-36	0.2		DRY	DRY	DRY	DRY
Radioactivity (Bq/L)							
Tritium	EP6-06	3.7	740	-0.6	-1.5	1.7	0.5
	EP6-08	3.7		-1.4	-1.3	2.8	0.4
	EP6-09	3.7		0.3	1.0	3.1	0.8
	K6-01S	3.7		4.0	3.2	5.7	4.0
	K6-19	3.7		9.9	9.8	12.0	8.2
	K6-36	88		DRY	DRY	DRY	DRY
Uranium (total)	EP6-06	0.13	0.74	0.02	0.03	0.06	0.03
	EP6-08	0.06		0.01	0.04	0.03	0.07, 0.08, 0.10
	EP6-09	0.14		0.07	0.08	0.08	0.07
	K6-01S	1.00		0.12	0.16	0.17	0.15
	K6-19	0.27		0.06	0.15	0.07	0.13
	K6-36	0.05		DRY	DRY	DRY	DRY
Gross alpha	EP6-06	0.29	0.56	-0.05	-0.02	0.00	-0.03
	EP6-08	0.15		-0.05	-0.01	0.06	0.01
	EP6-09	0.18		-0.17	0.08	0.07	-0.09
	K6-01S	0.95		-0.15	0.20	0.02	-0.59
	K6-19	0.34		-0.07	0.04	0.07	0.06
	K6-36	0.07		DRY	DRY	DRY	DRY
Gross beta	EP6-06	0.79	1.85	0.29	0.30	0.50	0.31
	EP6-08	0.79		0.37	0.47	0.40	0.42
	EP6-09	0.79		0.41	0.43	0.34	0.33
	K6-01S	2.13		0.75	0.58	0.67	0.60
	K6-19	0.79		0.33	0.35	0.35	0.28
	K6-36	0.97		DRY	DRY	DRY	DRY
Volatile organic compounds (μg/L, EPA method 8260)							
Benzene	EP6-06	0.5	1	< 1 [(a)]	< 0.5	< 0.5	< 0.5
	EP6-08	0.5		< 1	< 0.5	< 0.5	< 0.5
	EP6-09	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-01S	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-19	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-36	0.5		DRY	DRY	DRY	DRY
Carbon disulfide	EP6-06	5	none	< 1	< 5	< 5	< 5
	EP6-08	5		< 1	< 5	< 5	< 5
	EP6-09	5		< 1	< 5	< 5	< 5
	K6-01S	5		< 1	< 5	< 5	< 5
	K6-19	5		< 1	< 5	< 5	< 5
	K6-36	5		DRY	DRY	DRY	DRY

Table A-1. Pit 6 post-closure monitoring plan constituents of concern (COCs) detection monitoring wells, SLs, MCLs, and quarterly analytical results for 2007.

				Quarter			
COC (units)	**Well**	**SL**	**MCL**	**First**	**Second**	**Third**	**Fourth**
Volatile organic compounds (μg/L, EPA method 8260) (cont.)							
Chloroform	EP6-06	0.5	80	< 1[(a)]	< 0.5	< 0.5	< 0.5
	EP6-08	1.0		< 1	< 0.5	0.8	< 0.5
	EP6-09	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-01S	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-19	1.5		< 1	< 0.5	< 0.5	< 0.5
	K6-36	0.5		DRY	DRY	DRY	DRY
1,2-dichloroethane	EP6-06	0.5	0.5	< 1[(a)]	< 0.5	< 0.5	< 0.5
	EP6-08	0.5		< 1	< 0.5	< 0.5	< 0.5
	EP6-09	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-01S	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-19	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-36	0.5		DRY	DRY	DRY	DRY
Cis-1,2-dichloroethene	EP6-06	0.5	6	< 1[(a)]	< 0.5	< 0.5	< 0.5
	EP6-08	0.5		< 1	< 0.5	< 0.5	< 0.5
	EP6-09	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-01S	7.0		2.3	2.4	2.3	2.2
	K6-19	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-36	0.5		DRY	DRY	DRY	DRY
Ethyl benzene	EP6-06	0.5	700	< 1[(a)]	< 0.5	< 0.5	< 0.5
	EP6-08	0.5		< 1	< 0.5	< 0.5	< 0.5
	EP6-09	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-01S	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-19	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-36	0.5		DRY	DRY	DRY	DRY
Methylene chloride	EP6-06	1	5	< 1	< 1	< 1	< 1
	EP6-08	1		< 1	< 1	< 1	< 1
	EP6-09	1		< 1	< 1	< 1	< 1
	K6-01S	1		< 1	< 1	< 1	< 1
	K6-19	1		< 1	< 1	< 1	< 1
	K6-36	1		DRY	DRY	DRY	DRY
Tetrachloroethene	EP6-06	0.5	5	< 1[(a)]	< 0.5	< 0.5	< 0.5
(PCE)	EP6-08	1.6		1.4	1.4	1.7, 1.4, 1.2	1.3
	EP6-09	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-01S	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-19	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-36	1.0		DRY	DRY	DRY	DRY
Toluene	EP6-06	0.5	150	< 1[(a)]	< 0.5	< 0.5	< 0.5
	EP6-08	0.5		< 1	< 0.5	< 0.5	< 0.5
	EP6-09	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-01S	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-19	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-36	0.5		DRY	DRY	DRY	DRY
1,1,1-trichloroethane	EP6-06	0.5	200	< 1[(a)]	< 0.5	< 0.5	< 0.5
	EP6-08	0.5		< 1	< 0.5	< 0.5	< 0.5
	EP6-09	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-01S	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-19	0.5		< 1	< 0.5	< 0.5	< 0.5
	K6-36	0.5		DRY	DRY	DRY	DRY

Table A-1. Pit 6 post-closure monitoring plan constituents of concern (COCs) detection monitoring wells, SLs, MCLs, and quarterly analytical results for 2007.

				Quarter			
COC (units)	**Well**	**SL**	**MCL**	**First**	**Second**	**Third**	**Fourth**
Volatile organic compounds (μg/L, EPA method 8260) (cont.)							
Trichloroethene (TCE)	EP6-06	0.5	5	< 0.5	< 0.5	< 0.5	< 0.5
	EP6-08	0.5		0.5	< 0.5	0.8, 0.6, 0.6	0.6
	EP6-09	17		7.7	7.6	9.8	7.4
	K6-01S	1.5		< 0.5	< 0.5	< 0.5	< 0.5
	K6-19	13		3.1	1.5	3.2	2.7
	K6-36	2.1		DRY	DRY	DRY	DRY
Xylenes (total)	EP6-06	1	1750	< 2[a]	< 0.5	< 0.5	< 0.5
	EP6-08	1		< 2	< 0.5	< 0.5	< 0.5
	EP6-09	1		< 2	< 0.5	< 0.5	< 0.5
	K6-01S	1		< 2	< 0.5	< 0.5	< 0.5
	K6-19	1		< 2	< 0.5	< 0.5	< 0.5
	K6-36	1		DRY	DRY	DRY	DRY
Perchlorate (μg/L)	EP6-06	4.7	6[b]	< 4	< 4	< 4	< 4
	EP6-08	4		< 4	< 4	< 4	< 4
	EP6-09	4		< 4	< 4	< 4	< 4
	K6-01S	4		< 4	< 4	< 4	< 4
	K6-19	27.5		< 4	< 4	< 4	< 4
	K6-36	14.4		DRY	DRY	DRY	DRY

[a] The analytical laboratory reported reporting limits different than those agreed upon with our contract, LLNL corrected this issue for VOCs reported in the second quarter 2007 data.

[b] California state action level.

Table A-2. Pit 6 detection monitoring quarterly ground water physical parameters for 2007.

Detection well	Quarter 2007	Date sampled	GWE[a] (ft)	Temp. (°C)	pH (ph units)	Specific conductivity (μmho/cm)	TDS[b]
EP6-06	1	24-Jan-07	661.32	19.5	7.46	1317	810
	2	3-Apr-07	660.25	24.3	7.36	1038	840
	3	10-Jul-07	660.49	22	7.65	1309	840
	4	2-Oct-07	660.28	22.3	7.75	1188	860
EP6-08	1	30-Jan-07	652.71	20.9	7.28	1127	730
	2	3-Apr-07	654.38	25.3	7.05	900.4	720
	3	2-Jul-07	652.81	21.2	6.95	1129	760
	4	2-Oct-07	649.36	20.8	7.66	1059	780
EP6-09	1	30-Jan-07	664.44	20	7.19	1596	1100
	2	2-Apr-07	664.20	25.5	7.22	1276	1000
	3	2-Jul-07	664.15	23.2	7.52	1768	1000
	4	3-Oct-07	664.08	21.9	7.76	1472	1100
K6-01S	1	24-Jan-07	664.43	21.2	7.00	4101	3200
	2	2-Apr-07	664.20	22.7	7.09	3855	3000
	3	2-Jul-07	664.10	23	7.18	3806	3100
	4	3-Oct-07	663.99	21.7	7.10	3421	3000
K6-19	1	31-Jan-07	663.81	20.2	7.35	1188	740
	2	2-Apr-07	663.66	24.2	7.49	1138	710
	3	2-Jul-07	663.60	24.2	7.23	1168	740
	4	3-Oct-07	663.50	21.3	7.33	1049	740
K6-36	1	31-Jan-07	DRY	DRY	DRY	DRY	DRY
	2	3-Apr-07	DRY	DRY	DRY	DRY	DRY
	3	2-Jul-07	DRY	DRY	DRY	DRY	DRY
	4	3-Oct-07	DRY	DRY	DRY	DRY	DRY

[a] Ground water elevation (water table elevation in feet above mean sea level).

[b] Total dissolved solids.

Appendix B

Tables of Ground Water Measurements for Corrective Action Monitoring Wells

Table B-1. Water elevation (GWE) measurements in Pit 6 ground water monitoring wells, fourth quarter 2007.

Well	Date sampled	GWE (ft above MSL)
BC6-10	23-Oct-07	659.3
BC6-13	23-Oct-07	DRY
CARNRW1	3-Oct-07	636.4
CARNRW1	23-Oct-07	636.2
CARNRW2	23-Oct-07	NM
CARNRW3	23-Oct-07	661.3
CARNRW4	23-Oct-07	636.2
EP6-06	2-Oct-07	660.3
EP6-06	23-Oct-07	657.7
EP6-07	23-Oct-07	649.8
EP6-08	2-Oct-07	649.4
EP6-08	23-Oct-07	649.3
EP6-09	3-Oct-07	664.1
EP6-09	23-Oct-07	663.8
K6-01	23-Oct-07	663.9
K6-01S	3-Oct-07	664.0
K6-01S	23-Oct-07	663.8
K6-03	23-Oct-07	649.6
K6-04	23-Oct-07	650.6
K6-14	23-Oct-07	657.1
K6-15	23-Oct-07	DRY
K6-16	23-Oct-07	660.7
K6-17	23-Oct-07	654.7
K6-18	23-Oct-07	660.3
K6-19	3-Oct-07	663.5
K6-19	23-Oct-07	661.4
K6-21	23-Oct-07	DRY
K6-22	23-Oct-07	646.0
K6-23	23-Oct-07	656.4
K6-24	23-Oct-07	648.8
K6-25	23-Oct-07	660.6
K6-26	23-Oct-07	649.6
K6-27	23-Oct-07	647.9
K6-32	23-Oct-07	DRY
K6-33	23-Oct-07	640.9
K6-34	23-Oct-07	636.9
K6-35	23-Oct-07	649.6
K6-36	23-Oct-07	DRY/CB
W-33C-01	23-Oct-07	630.9
W-34-01	23-Oct-07	675.0
W-34-02	23-Oct-07	651.4
W-PIT6-1819	23-Oct-07	636.7

Table B-2. Volatile organic compounds detected in Pit 6 ground water samples, fourth quarter 2007.

VOCs detected	Well	Date sampled	Type	Result (µg/L)
VOCs (EPA 8260)				
cis-1,2-Dichloroethene	K6-01S	3-Oct-07	RTN	2.2
1,2-Dichloroethene (total)	K6-01S	3-Oct-07	RTN	2.2
Tetrachloroethene	EP6-08	2-Oct-07	RTN	1.3
Trichloroethene	EP6-08	2-Oct-07	RTN	0.58
Trichloroethene	EP6-09	3-Oct-07	RTN	7.4
Trichloroethene	K6-19	3-Oct-07	RTN	2.7

[a] Routine sample.

[b] Resample and retest sample.

Table B-3. Tritium activity measurements in Pit 6 ground water samples, fourth quarter 2007.

Well	Date sampled	Routine or Duplicate	Activity (pCi/L)	Activity (Bq/L)
CARNRW1	3-Oct-07	RTN	<100	<3.7
CARNRW1	3-Oct-07	DUP	<200	<7.4
CARNRW1	1-Nov-07	RTN	<100	<3.7
CARNRW1	1-Nov-07	DUP	<100	<3.7
CARNRW1	3-Dec-07	RTN	<100	<3.7
CARNRW1	3-Dec-07	DUP	<100	<3.7
CARNRW2	3-Oct-07	RTN	<100	<3.7
CARNRW2	3-Oct-07	DUP	<200	<7.4
CARNRW2	1-Nov-07	RTN	<100	<3.7
CARNRW2	1-Nov-07	DUP	<100	<3.7
CARNRW2	3-Dec-07	RTN	<100	<3.7
CARNRW2	3-Dec-07	DUP	<100	<3.7
CARNRW3	3-Oct-07	RTN	<100	<3.7
CARNRW3	3-Oct-07	DUP	<200	<7.4
CARNRW3	1-Nov-07	RTN	<100	<3.7
CARNRW3	1-Nov-07	DUP	<100	<3.7
CARNRW3	3-Dec-07	RTN	<100	<3.7
CARNRW3	3-Dec-07	DUP	<100	<3.7
CARNRW4	3-Oct-07	RTN	<100	<3.7
CARNRW4	3-Oct-07	DUP	<200	<7.4
CARNRW4	1-Nov-07	RTN	<100	<3.7
CARNRW4	1-Nov-07	DUP	<100	<3.7
CARNRW4	3-Dec-07	RTN	<100	<3.7
CARNRW4	3-Dec-07	DUP	<100	<3.7
EP6-06	2-Oct-07	RTN	<100	<3.7
EP6-08	2-Oct-07	RTN	<100	<3.7
EP6-09	3-Oct-07	RTN	<100	<3.7
K6-01S	3-Oct-07	RTN	108	4
K6-17	9-Oct-07	RTN	<100	<3.7
K6-17	9-Oct-07	DUP	<100	<3.7
K6-19	3-Oct-07	RTN	221	8.2
K6-22	9-Oct-07	RTN	<100	<3.7
K6-34	4-Oct-07	RTN	<100	<3.7
K6-36	3-Oct-07	RTN	DRY	DRY
W-PIT6-1819	4-Oct-07	RTN	173	6.4

Table B-4. Perchlorate and nitrate concentrations in Pit 6 ground water samples, fourth quarter 2007

Well	Date sampled	Routine or Duplicate	Perchlorate (μg/L)	Nitrate (as NO3) (mg/L)
CARNRW1	3-Oct-07	RTN	<4	<0.5
CARNRW1	3-Oct-07	DUP	<4	<0.5
CARNRW1	1-Nov-07	RTN	<4	<0.5
CARNRW1	1-Nov-07	DUP	<4	<0.5
CARNRW1	3-Dec-07	RTN	<4	<0.5
CARNRW1	3-Dec-07	DUP	<4	<0.5
CARNRW2	3-Oct-07	RTN	<4	<0.5
CARNRW2	3-Oct-07	DUP	<4	<0.5
CARNRW2	1-Nov-07	RTN	<4	<0.5
CARNRW2	1-Nov-07	DUP	<4	<0.5
CARNRW2	3-Dec-07	RTN	<4	<0.5
CARNRW2	3-Dec-07	DUP	<4	<0.5
CARNRW3	3-Oct-07	RTN	<4	<0.5
CARNRW3	3-Oct-07	DUP	<4	<0.5
CARNRW3	1-Nov-07	RTN	<4	<0.5
CARNRW3	1-Nov-07	DUP	<4	<0.5
CARNRW3	3-Dec-07	RTN	<4	<0.5
CARNRW3	3-Dec-07	DUP	<4	<0.5
CARNRW4	3-Oct-07	RTN	<4	<0.5
CARNRW4	3-Oct-07	DUP	<4	<0.5
CARNRW4	1-Nov-07	RTN	<4	<0.5
CARNRW4	1-Nov-07	DUP	<4	<0.5
CARNRW4	3-Dec-07	RTN	<4	<0.5
CARNRW4	3-Dec-07	DUP	<4	<0.5
EP6-06	2-Oct-07	RTN	<4	<0.5
EP6-08	2-Oct-07	RTN	<4	<0.5
EP6-09	3-Oct-07	RTN	<4	2.6
K6-01S	3-Oct-07	RTN	<4	<2.5
K6-19	3-Oct-07	RTN	<4	<0.5
K6-36	3-Oct-07	DRY	DRY	DRY

Table B-5. Pit 6 monitoring locations, monitoring functions, associated monitoring programs, COCs, monitoring frequencies, and third quarter 2007 sampling summary.

Monitoring location	Monitoring function	Monitoring program	COCs[(a)] (sampling frequency)	COCs analyzed	Reason(s), if not completed
K6-17	guard well	CAMP	P (Q), S (SA)	P	
K6-22	guard well	CAMP	P (Q), S (SA)	P	
K6-34	guard well	CAMP	P (Q), S (SA)	P	
W-PIT6-1819	guard well	CAMP	P (Q), S (SA)	P	
SPRING7	plume tracking spring	CAMP	P (SA), S (A)	none	DRY
SPRING15	plume tracking spring	CAMP	P (SA), S (A)	none	DRY
BC6-10	plume tracking well	CAMP	P (SA), S (A)	none	Not Scheduled
BC6-13	plume tracking well	CAMP	P (SA), S (A)	none	DRY
EP6-07	plume tracking well	CAMP	P (SA), S (A)	none	Not Scheduled
K6-01	plume tracking well	CAMP	P (SA), S (A)	none	DRY
K6-03	plume tracking well	CAMP	P (SA), S (A)	none	Not Scheduled
K6-04	plume tracking well	CAMP	P (SA), S (A)	none	Not Scheduled
K6-14	plume tracking well	CAMP	P (SA), S (A)	none	Not Scheduled
K6-15	plume tracking well	CAMP	P (SA), S (A)	none	DRY
K6-16	plume tracking well	CAMP	P (SA), S (A)	none	Not Scheduled
K6-18	plume tracking well	CAMP	P (SA), S (A)	none	Not Scheduled
K6-21	plume tracking well	CAMP	P (SA), S (A)	none	DRY
K6-23	plume tracking well	CAMP	P (SA), S (A)	none	Not Scheduled
K6-24	plume tracking well	CAMP	P (SA), S (A)	none	Not Scheduled
K6-25	plume tracking well	CAMP	P (SA), S (A)	none	Not Scheduled
K6-26	plume tracking well	CAMP	P (SA), S (A)	none	Not Scheduled
K6-27	plume tracking well	CAMP	P (SA), S (A)	none	Not Scheduled
K6-32	plume tracking well	CAMP	P (SA), S (A)	none	Not Scheduled
K6-33	plume tracking well	CAMP	P (SA), S (A)	none	Not Scheduled
K6-35	plume tracking well	CAMP	P (SA), S (A)	none	Not Scheduled
W-33C-01	plume tracking well	CAMP	P (SA), S (A)	none	Not Scheduled
EP6-06	release detection well	DMP	All (Q)	All	
EP6-08	release detection well	DMP	All (Q)	All	
EP6-09	release detection well	DMP	All (Q)	All	
K6-01S	release detection well	DMP	All (Q)	All	
K6-19	release detection well	DMP	All (Q)	All	
K6-36	release detection well	DMP	All (Q)	none	DRY
CARNRW1	water supply well	CAMP	P (M), S (M)	P,S	
CARNRW2	water supply well	CAMP	P (M), S (M)	P,S	
CARNRW3	water supply well	CAMP	P (M), S (M)	P,S	
CARNRW4	water supply well	CAMP	P (M), S (M)	P,S	

[(a)] P means the primary COCs tritium and VOCs. S means the secondary COCs perchlorate and nitrate. All means all DMP COCs (see **Table C-1** for a list). (M) means sampled monthly. (Q) means sampled quarterly. (SA) means sampled semiannually (done first and third quarters of year). (A) means sampled annually (done first quarter of year).

Appendix C

Statistical Methods for Detection Monitoring

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Statistical Methods for Detection Monitoring

Monitoring and reporting provisions of the CERCLA closure and post-closure plan for the Pit 6 landfill require the use of statistical methods from the *California Code of Regulations* (CCR), Title 23, Division 3, Chapter 15, Section 2550.7 (Ferry *et al*., 1998).

We use statistically determined limits of concentration (SLs) to detect potential releases of constituents of concern (COCs) to ground water from solid wastes contained in the Pit 6 landfill. We employ two statistical methods, prediction intervals (PIs) and control charts (CCs), to generate SLs. Both methods are sensitive to COC concentration increases. Both methods are cost-effective, requiring only one measurement of a COC per quarter per monitoring well.

We prefer the PI method when COC concentrations in ground water are similar upgradient and downgradient from the monitored unit. We use parametric PI methods when the upgradient COC concentration data are all above the detection limit and the data are approximately normally distributed. We may use parametric methods on log-transformed data, if the transformed data follow a normal distribution. Nonparametric PI methods are more effective when the data cannot be transformed to a normal distribution, or when they contain nondetections.

When the concentration of a COC is spatially variable in the vicinity of a monitored unit, we develop a control chart for each downgradient monitoring well. The control chart compares each new quarterly COC measurement with its concentration history for that well.

Wherever sufficient historical detections exist, we calculate an SL such that any future measurement has approximately a 1-in-100 chance of exceeding the SL, when no change in concentration has actually occurred. This yields a statistical test with a significance level of approximately 0.01. Where historical detections exist, but nondetections constitute part of the data, we set the SL equal to the highest concentration measured. If historical analyses of a COC show all nondetections, then we set the SL equal to the analytical reporting limit (RL). When a routine COC measurement exceeds an SL, we perform two discrete retests. This method of data verification is in accordance with CCR Title 23, Chapter 15, Section 2550.7.

Constituents of Concern

COCs were identified for monitoring in the ground water at the Pit 6 landfill prior to its closure (Ferry *et al.* 1998). COCs, as defined by CCR Title 22, Chapter 15, are waste

constituents, their reaction products, or hazardous constituents that are reasonably expected to be in or derived from waste buried in Pit 6. The current COCs for Pit 6 are listed in **Table C-1** below.

Table C-1. Pit 6 COCs, typical analytical reporting limit (RL), concentration limit (CL)[a] and statistical limit (SL) for each of the six detection monitoring wells.

Constituent of concern (COC)	Typical analytical RL (units)	Well EP6-06 CL; SL	Well EP6-08 CL; SL	Well EP6-09 CL; SL	Well K6-01S CL; SL	Well K6-19 CL; SL	Well K6-36 CL; SL
1,1,1-TCA	0.5 μg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
1,2-DCA	0.5 μg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Cis-1,2-DCE	0.5 μg/L	<RL; RL	<RL; RL	<RL; RL	5.4; 7.0	<RL; RL	<RL; RL
Chloroform	0.5 μg/L	<RL; RL	0.1; 1.0	<RL; RL	<RL; RL	0.2; 1.5	<RL; RL
Methylene chloride	0.5 μg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
PCE	0.5 μg/L	<RL; RL	0.4; 1.6	<RL; RL	<RL; RL	<RL; RL	0.5; 1.0
TCE	0.5 μg/L	<RL; RL	<RL; RL	14; 17	1.1; 1.5	8.2; 13	0.8; 2.1
Benzene	0.5 μg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Ethylbenzene	0.5 μg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Toluene	0.5 μg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Total xylenes	1.0 μg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Beryllium	0.5 μg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Mercury	0.2 μg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Carbon disulfide	5.0 μg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Perchlorate	4.0 μg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	10.2; 27.5	5.3; 14.4
Tritium	100 pCi/L	RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	2060; 2390
Uranium (total)	0.5 pCi/L	1.9; 3.6	1.2; 1.5	2.1; 3.7	6.6; 27	3.2; 7.2	0.5; 1.4
Gross alpha[b]	2 pCi/L	2.7; 7.7	0.9; 4.0	1.0; 4.9	7.0; 26	2.0; 9.2	<RL; RL
Gross beta[b]	2 pCi/L	8.6; 21	8.6; 21	8.6; 21	14; 58	8.6; 21	9.8; 26

[a] CL (concentration limit) is equivalent to the background concentration of a COC.

[b] Gross alpha and gross beta are surrogates for ^{125}Sb, ^{137}Cs, ^{60}Co, ^{22}Na, ^{90}Sr, ^{204}Tl, and ^{232}Th.

Chlorinated VOCs (including TCE, PCE, 1,2-DCA, 1,1,1-TCA, methylene chloride, chloroform, benzene, toluene, ethylbenzene, and total xylenes) were detected historically in ground water and/or in soil adjacent to Pit 6. These VOCs are COCs.

Beryllium and mercury are COCs because they are listed in the waste disposal records for Pit 6.

Nine radionuclide COCs are associated with waste buried in Pit 6. They are ^{125}Sb, ^{137}Cs, ^{60}Co, ^{22}Na, ^{90}Sr, ^{204}Tl, ^{232}Th, ^{238}U, and tritium. Gross alpha and gross beta

radioactivity are used as surrogates for seven of these nuclides, but not for uranium and tritium, which are measured separately (**Table C-1**).

A minor tritium release occurred prior to closure of Pit 6 and is the object of a continuing LLNL CERCLA investigation. The detection monitoring well BC6-12 was destroyed during year 2000, because it was screened across two water-bearing zones and could have provided a conduit for tritium in the shallower zone to contaminate ground water in the deeper zone. Well BC6-12 was replaced by well K6-36, which was constructed adjacent to it. Well K6-36 is screened only in the shallow water-bearing zone. Our calculated COC SLs for replacement well K6-36 are shown (**Table C-1)**.

A post-closure LLNL CERCLA study detected perchlorate in ground water downgradient of Pit 6. Consequently, perchlorate was added to the COC list and we have calculated SLs for this chemical (**Table C-1**).

Pesticides were not detected over an 18-month period (6 quarterly sampling events) following pit closure and were removed from the COC list.

Phthalates were not designated as COCs, because they were rarely detected prior to pit closure. However, since post-closure monitoring began in 1998, we have detected bis(2-ethylhexyl)phthalate (also known as di[2-ethylhexyl]phthalate, or DEHP) in ground water both upgradient and downgradient from Pit 6.

Table C-2 lists COCs that have indicated statistically significant evidence of release to ground water since post-closure monitoring began in 1998. **Table C-2** also lists the date of our 7-day letter notification to CVRWQCB and the status of any additional investigation of the COC. Note that 1,2-DCA has not been detected since 1998.

Table C-2. Pit 6 COCs showing statistical evidence of post-closure release.

COC	Date of 7-day letter report	Status of release investigation
1,2-DCA	10/13/98[a]	Transferred to ERD[b]
Perchlorate	11/08/02[c]	Retests did not confirm a release
Uranium	05/10/04[d]	Retest indicates a natural source
TCE	09/11/07[e]	Transferred to ERD[b]

[a] Galles, H. L., to S. Timm (1998), Letter: *Statistically Significant Evidence for a Release of 1,2-Dichloroethane from Pit 6* (WGMG98:282, October 13, 1998).

[b] LLNL Environmental Restoration Department.

[c] Raber, E., to T. Park, K. Setian, and S. Timm (2002), Letter*: Statistically Significant Evidence for a Release of Perchlorate from Lawrence Livermore National Laboratory Experimental Test Site (Site 300) Pit 6* (WGMG02-182, November 8, 2002).

[d] Raber, E., to T. Park, K. Setian, and S. Timm (2004), Letter: *Statistically Significant Evidence for a Release of Uranium from Lawrence Livermore National Laboratory Experimental Test Site (Site 300) Pit 6* (WGMG04-055, May 10, 2004).

[e] *Goodwin,S., to S. Timm (2007), Letter: Statistically Significant Evidence for a Release of Trichloroethene (TCE) from Lawrence Livermore National Laboratory Experimental Test Site (Site 300) Pit 6* (WGMG07-109, September 11, 2007).

Appendix D

Changes in Monitoring Programs or Methods

Appendix D

Changes in Monitoring Programs or Methods

LLNL implemented a compliance monitoring program during the second quarter of 1998 for the CERCLA-closed Pit 6 landfill at Site 300. The program is described in detail in Ferry *et al.*, 1998.

During 2000, two new monitoring wells, designated K6-35 and K6-36, replaced monitoring wells BC6-11 and BC6-12, which were destroyed by grouting. Well K6-36, which is screened in the first (shallower) of two water-bearing zones, replaced well BC6-12 for release detection. Well K6-35, screened in the next deeper water-bearing zone, is used for corrective-action assessment.

By request of the CVRWQCB, we added perchlorate to the list of Pit 6 COCs during the third quarter of 2000.

By request of the CVRWQCB, since the third quarter of 2000, we have provided a table of information (**Table B-5)** that lists the Pit 6 CERCLA monitoring wells, their monitoring program assignments, their sampling frequencies, the COCs they monitor, and a reason if they were not sampled during the reported quarter.

During 2001, quarterly tritium monitoring was expanded to include CERCLA well K6-33 and the private, off-site, water-supply wells designated CARNRW1 and CARNRW2. During 2002 a new CERCLA guard well was completed downgradient from Pit 6 adjacent to the Site 300 boundary. This well is identified as W-PIT6-1819.

Beginning January 1, 2003 the CAMP sampling schedule and COCs changed as described in the *Compliance Monitoring Plan/Contingency Plan for Interim Remedies at Lawrence Livermore National Laboratory Site 300* (Ferry, *et al.*, 2002). An expanded set of CAMP wells and springs have been sampled semiannually for tritium and VOCs, and annually for nitrate and perchlorate, while DMP well monitoring remains essentially unchanged. However, upgradient wells K6-03, K6-04, K6-15, and K6-32, which were formerly sampled quarterly for all the DMP COCs listed in **Table C-1**, are now designated to be CAMP plume-tracking wells and are sampled semiannually for tritium and VOCs and annually for nitrate and perchlorate only. As of fourth quarter 2004, VOCs have been reported as Total VOCs (TVOCs) to be consistent with other reports.

During 2006, reporting limits provided by the analytical laboratory for Environmental Protection Agency (EPA) Methods 200.8:Be, 601, and 624 changed due to a transition the contract laboratory's data management system. Essentially, the analytical laboratory had agreed to provide detection limits for EPA Methods 601 and

624, which were the same as EPA Method 8260. However, after the data management system change, the labs began reporting only what was specified in our contracts. As a result of this change in practice, the revisions have affected the reported non-detect concentrations for the following COCs: beryllium, benzene, chloroform, 1,2-dichloroethane (cis-1,2-DCE), cis-1,2-dichloroethene, ethylbenzene, PCE, toluene, 1,1,1-trichloroethane, and total xylenes. In all these cases, the different reporting limits represent practical quantitation limits (PQLs) selected by the analytical laboratory, not a change in measured concentrations. LLNL examined if contract modifications, changes in analytical suites, or a change of method would best solve the problem. Starting in second quarter 2007, we began reporting VOCs measured with EPA method 8260 and metals with the WGMGMET3 metal contract suite which provide detection limits consistent with, or lower than, past reports. During the third quarter of 2007, the VOCs PQLs were reported correctly; however, the lab continued to report incorrect PQLs for Be. The analytical Laboratory was contacted and promised the values would be correct for the fourth quarter data.

Appendix E

Quality Assurance Sample Results

Table E-1. Quality assurance samples from Pit 6 during the fourth quarter 2007.

Constituent	3-Oct Routine CARNRW1	3-Oct Duplicate CARNRW1	3-Oct Field Blank PIT6FB	Units
Total dissolved solids (TDS)	ND[a]	ND	8	mg/L
Beryllium	<0.5	<0.2	<0.2	µg/L
Mercury	<0.2	<0.2	<0.2	µg/L
Nitrate (as NO3)	<0.5	<0.5	<0.5	mg/L
Perchlorate	<4	<4	<4	µg/L
1,1,1-Trichloroethane	<1	<1	<0.5	µg/L
1,1,2,2-Tetrachloroethane	<1	<1	<0.5	µg/L
1,1,2-Trichloroethane	<1	<1	<0.5	µg/L
1,1-Dichloroethane	<1	<1	<0.5	µg/L
1,1-Dichloroethene	<1	<1	<0.5	µg/L
1,2-Dichloroethane	<1	<1	<0.5	µg/L
1,2-Dichloroethene (total)	<1	<1	<1	µg/L
1,2-Dichloropropane	<0.5	<1	<0.5	µg/L
cis-1,2-Dichloroethene	<1	<1	<0.5	µg/L
cis-1,3-Dichloropropene	<1	<1	<0.5	µg/L
2-Butanone	<20	<10	<10	µg/L
2-Chloroethylvinylether	<20	<10	<10	µg/L
2-Hexanone	<20	<10	<20	µg/L
4-Methyl-2-pentanone	<20	<10	<10	µg/L
Acetone	<10	<10	<10	µg/L
Acrolein	ND	ND	<50	µg/L
Acrylonitrile	ND	ND	<50	µg/L
Benzene	<1	<1	<0.5	µg/L
Bromodichloromethane	<1	<1	<0.5	µg/L
Bromoform	<1	<1	<0.5	µg/L
Bromomethane	<2	<2	<1	µg/L
Carbon disulfide	<1	<1	<5	µg/L
Carbon tetrachloride	<1	<1	<0.5	µg/L
Chlorobenzene	<1	<1	<0.5	µg/L
Chloroethane	<2	<2	<0.5	µg/L
Chloroform	<1	<1	0.9	µg/L
Chloromethane	<2	<2	<0.5	µg/L
Dibromochloromethane	<1	<1	<0.5	µg/L
Dichlorodifluoromethane	<2	<1	<0.5	µg/L
Ethanol	ND	ND	<1000	µg/L
Ethylbenzene	<1	<1	<0.5	µg/L
Freon 113	<1	<1	<0.5	µg/L
Methylene chloride	<1	<1	<1	µg/L
Styrene	<1	<1	<0.5	µg/L
Tetrachloroethene	<1	<1	<0.5	µg/L
Toluene	<1	<1	<0.5	µg/L
Total xylene isomers	<2	<2	<0.5	µg/L
trans-1,2-Dichloroethene	<1	<1	<0.5	µg/L

Table E-1. Quality assurance samples from Pit 6 during the fourth quarter 2007.

Constituent	3-Oct Routine CARNRW1	3-Oct Duplicate CARNRW1	3-Oct Field Blank PIT6FB	Units
trans-1,3-Dichloropropene	<1	<1	<0.5	μg/L
Trichloroethene	<0.5	<0.5	<0.5	μg/L
Trichlorofluoromethane	<1	<1	<0.5	μg/L
Vinyl acetate	<20	<1	<20	μg/L
Vinyl chloride	<1	<1	<0.5	μg/L
Tritium	-0.097 ± 2.2	-0.36 ± 1.9	0.91 ± 2.0	Bq/L
Gross alpha	-0.15 ± 0.096	0.0046 ± 0.031	-0.017 ± 0.010	Bq/L
Gross beta	0.32 ± 0.078	0.48 ± 0.11	-0.017 ± 0.030	Bq/L
Uranium (total)	ND	ND	0.0011 ± 0.00093	Bq/L

[a] This quarter monitoring well K6-36 was selected as the duplicate analysis, however it was dry. Therefore, data collected on the same day from well CARNRW1 were used to demonstrate quality assurance. Unfortunately, not all the analytes were measured in CARNRW1, so that there was No Data (ND) available for display.

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